REVIEW ARTICLES

Richard P. Cambria, MD, Section Editor

Juxtarenal aortic aneurysm repair

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Objectives: **Juxtarenal aortic aneurysms (JAA) account for approximately 15% of abdominal aortic aneurysms. Despite advances in endovascular aneurysm repair, open repair requiring suprarenal aortic cross-clamping is still the treatment of choice for JAA. We performed a systematic review of the literature to determine perioperative mortality and postoperative renal dysfunction after open repair for non-ruptured JAA.**

Methods: **The Medline, Embase, and Cochrane databases were searched to identify all studies reporting non-ruptured JAA repair published between January 1966 and December 2008. Two independent observers selected studies for inclusion, assessed the methodologic quality of the included studies, and performed the data extraction. Study heterogeneity was assessed using forest plots and by calculating the between-study variance. Outcomes were perioperative mortality, postoperative renal dysfunction, and new onset of dialysis. Summary estimates with 95% confidence interval (95% CI) were calculated using a random effects model based on the binomial distribution.**

Results: **Twenty-one non-randomized cohort studies from 1986 to 2008, reporting on 1256 patients, were included. Heterogeneity between the studies was low. The mean perioperative mortality was 2.9% (95% CI, 1.8 to 4.6). The mean incidence of new onset of dialysis was 3.3% (95% CI, 2.4 to 4.5). Incidence of postoperative renal dysfunction could be derived from 13 studies and ranged from 0% to 39% (median, 18%). In seven studies, cold renal perfusion during suprarenal clamping was performed in order to preserve renal function; however, based upon the included data, definitive conclusions regarding its efficacy could not be drawn.**

Conclusions: **Open repair of non-ruptured JAA using suprarenal cross-clamping can be performed with acceptable perioperative mortality; however, postoperative deterioration of renal function is a common complication. Preservation of renal function after JAA repair requires further investigation. (J Vasc Surg 2010;52:760-7.)**

Juxtarenal aortic aneurysms (JAA) account for approximately 15% of abdominal aortic aneurysms (AAA).[1-10] By definition, suprarenal aortic cross-clamping is required for surgical repair, causing temporary renal artery occlusion that may lead to postoperative renal dysfunction, in some cases requiring (temporary) hemodialysis.

Standard endovascular aneurysm repair (EVAR) is not an option due to absence of an infrarenal neck. Fenestrated and branched aortic endografts have been developed and may be applied in selected patients with JAA. However, procedures are complex, technically challenging, and time consuming.[11,12] Currently, fenestrated or branched endografts are not commercially available and have not been approved by the Food and Drug Administration for use in the United States. Therefore, open repair of JAA remains the gold standard. The aim of the present study was to perform a systematic review of mortality and postoperative renal dysfunction in patients after non-ruptured open JAA repair. This review may serve as a benchmark for (future) endovascular procedures.

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Competition of interest: none.

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METHODS

This systematic review was performed according to the guidelines of the Dutch Cochrane Centre and the Meta-analysis Of Observational Studies in Epidemiology group (MOOSE).[13,14]

Search strategy. A computer-assisted search was performed by two independent investigators (V.J. and D.H.), with assistance of a clinical librarian. The medical databases Medline (from January 1966 to December 2008), Embase (from January 1988 to December 2008), and the Cochrane Database of Systematic Reviews (from 1990 to December 2008) were searched. The following combination of medical subject headings (MeSH) was used: abdominal aorta, aortic aneurysm, aortic rupture, abdominal aortic aneu-

rysm, renal circulation, renal insufficiency, renal artery obstruction, and renal artery. An additional search was performed using a combination of the following free text words: juxtarenal aneurysm, suprarenal aneurysm, pararenal aneurysm, and surgery. Electronic links to related articles and reference lists of selected articles were handsearched as well. A hand search of relevant journals and conference proceedings was not performed. We did not perform systematic searches for unpublished data or abstracts, nor were leading authors in the field contacted to retrieve more articles. After identifying relevant titles, the abstracts of these studies were read to decide if the study was suitable.

Study selection. Two authors (V.J. and D.H.) independently selected the articles based on full text review. All studies reporting mortality, incidence of acute renal dysfunction, or new onset of dialysis after open repair of non-ruptured juxtarenal aortic aneurysms were considered for inclusion. JAA were defined as aneurysms that involve the infrarenal abdominal aortic segment and extend up to and sometimes include the lower margins of the renal artery origins, requiring suprarenal cross-clamping during open aneurysm repair.[15] Studies reporting combined results of suprarenal, pararenal, and juxtarenal aneurysm repair or ruptured and non-ruptured repair were included only if specific results for non-ruptured JAA could be derived. Studies had to comprise a minimal number of 10 patients to be eligible for inclusion. We excluded studies reporting only endovascular aneurysm repair, hybrid techniques, aortic occlusive disease, or aortoiliac aneurysm repair in renal transplant patients. Only articles written in English or Dutch were included. To be eligible, articles had to describe original patient series. Studies containing duplicate material were excluded, and the larger of the studies, containing the best documented data, was included for analysis. Review articles, technical descriptions, and case reports were excluded. Discrepancies in judgment, if any, were resolved by discussion among the authors. Final inclusion occurred after consensus was reached.

Methodologic quality assessment. The methodologic quality of each included article was determined by the same two observers independently. Using a critical review checklist, study quality was assessed by whether the article fulfilled the following requirements:

1. a clear definition of the study population,
2. selection bias could be sufficiently excluded,
3. a clear description of method of intervention,
4. detailed description of outcomes,
5. data collection by independent or blinded observers,
6. follow up during the entire hospital stay up to discharge,
7. description of excluded patients and reasons for exclusion,
8. description of confounders.

Furthermore, all studies were evaluated using a list of seven detailed study characteristics. Each item was graded on a scale of 0 to 2, depending on the information available in the article. Quality score was assessed by whether the study reported a consecutive series, a prospective series, details of surgical indication, details on the surgical procedures, renal protective measures taken, incidence of postoperative renal dysfunction, and mortality rate. Discrepancies in methodologic assessment were resolved by discussion. Methodologic quality was not used as an exclusion criterion.

Data extraction. Two authors (V.J. and D.H.) extracted the data independently. Any disagreement was reconciled by repeat review of the studies in question. A standardized form was used to extract the data, which included publication year, country of origin, number of patients, age and gender of the patients, study design, preoperative renal dysfunction, aneurysm type, aneurysm size, details on surgical intervention, use of renal protective measures, 30-day or in-hospital mortality, and postoperative renal dysfunction. To be eligible, criteria for postoperative renal dysfunction had to be defined in the article, and data needed to be reported for individual patients, preferably but not exclusively based upon the RIFLE classification.[16] The RIFLE system characterizes renal dysfunction into Risk of renal dysfunction, Injury to the kidney, Failure or Loss of kidney function, and End-stage kidney disease. The mildest stage of acute kidney dysfunction is defined as an acute rise in serum creatinine level $>1.5\times$ or decrease of glomerular filtration rate(GFR) $>25\%$ or urine output $<0.5\ \mathrm{ml\,kg^{-1}\,h^{-1}}$ during 6 hours. Cumulative incidence of new onset hemodialysis was also retrieved. This included all patients who required temporary or permanent hemodialysis during postoperative hospital stay, but were not depended on dialysis preoperatively. Data were considered missing if they were not reported in a table or mentioned explicitly in the text. If the study described combined results for suprarenal aortic aneurysms (SAA) and JAA or ruptured and non-ruptured aneurysms, only data for non-ruptured JAA were extracted. Data were considered not retrievable if data were reported combined, but specific data for JAA repair could not be derived.

Statistical analysis. Proportions were transformed to a logit scale, and meta-analysis was performed using a random effects model. The exact binomial distribution was used to model the within-study variance in order to give more weight to studies in which a proportion was measured with higher precision. Random effect summary estimates of perioperative mortality and new onset of dialysis were presented together with 95% confidence intervals (95% CI). Study heterogeneity was assessed using forest plots and by calculating the between-study variance. Data analysis was performed using SAS 9 (SAS Institute Inc, Cary, NC), using the procedure for generalized mixed model (proc nlmixed). Continuous data were expressed as median and range.

RESULTS

The search identified 1680 studies, of which 54 articles were potentially eligible for inclusion after first inspection.

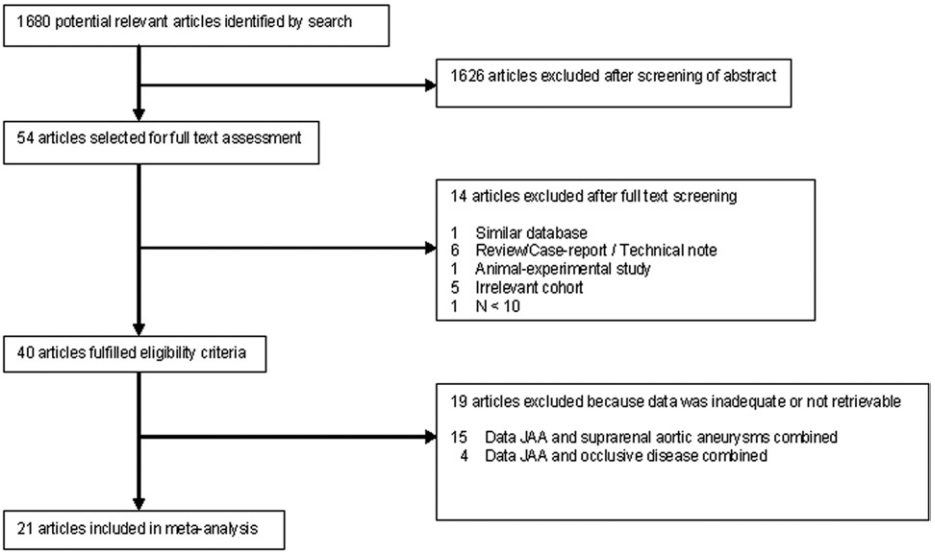

Fig 1. Flow chart illustrating study selection.

Study flow and reasons for exclusion are presented in Fig 1. One study was excluded because it reported on a similar database as one larger study.[17] One animal study,[18] three case reports,[19-21] one review article,[22] and two technical notes were excluded.[23,24] One study was excluded because it reported on a small case series.[25] We excluded four articles because they reported on JAA and thoracoabdominal aortic aneurysm repair, and data for JAA could not be retrieved.[26-29] One study described only infrarenal aortic aneurysm repair and was excluded.[30] Twenty-three studies described combined results of JAA and SAA repair or surgery for occlusive disease. From 19 studies, specific data on mortality or new onset of dialysis after non-ruptured open JAA repair could not be retrieved and were excluded,[31-49] resulting in 21 articles to be included in the systematic review.[1-10,15,50-59] The chance adjusted inter-reviewer agreement for study eligibility (kappa) was 0.77.

In four studies, combined results of JAA, SAA, and thoracoabdominal aortic aneurysms (TAA) were reported,[1,2,52,55] and three studies reported results of ruptured and non-ruptured JAA.[9,15,51] Specific results for non-ruptured JAA could be retrieved from all 21 articles. In total, 1256 patients were evaluated, with a median study size of 42 patients (range, 13-138 patients). Studies were published between 1986 and 2008 and reported on patients receiving open JAA repair between 1963 and 2006. Twelve studies were performed in the United States, six studies in Europe, and three in Japan. No randomized trials were found. All of the studies reported on results from a single center.

The assessment of study quality is presented in Table I. Methodological quality varied considerably between included studies. Most studies (n = 13) were retrospective; only four studies reported prospective data.[6,50-52] Ten authors presented consecutive patient series.[1,3,4,6,7,10,50,52,53,55] In four studies, JAA were not specifically defined.[10,53,58,59]

Meta analysis. Extracted data from the included studies is presented in Table II. Median aneurysm diameter was 6.1 cm (range, 5.8-6.8 cm). The definition of preoperative renal insufficiency varied between the studies from serum creatinine level >1.25 mg/dL to >2.0 mg/dL. The median proportion of preoperative renal insufficiency across studies was 16.7% (range, 0%-52%). Median renal ischemia time was 27 minutes (range, 19-44 minutes). Between-study variance was low for mortality after open JAA repair (.18 on logit scale, $P = .44$) and zero for new onset of dialysis (ie, no indication of heterogeneity beyond chance).

From 20 studies, perioperative mortality could be retrieved. Three studies defined mortality as in-hospital or within 30 days,[5,6,50] three studies presented in-hospital mortality,[7,54,57] and eight studies presented 30-day mortality.[2-4,10,15,51,56,59] One study reported mortality <90 days,[1] while in five studies, no definition for perioperative mortality was found.[8,9,52,53,55,58] Fig 2 represents the mortality rates in all studies after open JAA repair. The pooled estimate of perioperative mortality rate for non-ruptured JAA repair was 2.9% (95% confidence interval [CI], 1.8%-4.6%).

In 20 studies, postoperative new onset of temporary or permanent hemodialysis was presented. The pooled estimate of the cumulative incidence of new onset dialysis was 3.3% (95% CI, 2.4%-4.5%; Fig 3). In addition to new onset of dialysis, 19 authors reported incidence of postoperative renal dysfunction (Table III). However, in three articles, no criteria for postoperative renal dysfunction were mentioned, and three studies reported combined results for JAA and SAA or ruptured and non-ruptured JAA. All studies defined postoperative renal dysfunction based upon serum creatinine levels. None of the studies used GFR or urine output criteria. Various definitions for postoperative renal dysfunction were used, as is shown in Table III. Reported incidence of postoperative acute renal dysfunc-

Table I. Quality assessment of included studies

First author	*Year*	*Definition of study population*	*No selection bias*	*Method of intervention*	*Description of outcomes*	*Independent observers*	*Sufficient duration of follow–up*	*No selective loss to follow–up*	*Description of confounders*	*Quality score of description of study* characteristics**
Crawford	1986	+	+	+	+/−	−	+	+	+	6
Poulias	1992	+	+	+	+	−	+	+	+	9
Allen	1993	+	+	+	+	−	+	+	+	12
Nypaver	1993	+	+	+	+/−	−	+	+	+	10
Taylor	1994	+	+	−	+/−	−	+	+	−	6
Schneider	1997	+	+	+	+	−	+	+	+	12
Jean-Claude	1999	+	+	+	+/−	−	+	+	+	10
Guilini	2000	+	+	+	+/−	−	+	+	−	9
Sasaki	2000	+	+	+	+	−	+	+	+	7
Ayari	2001	+	+	−	+	−	+	+	+	8
Sarac	2002	+	+	+	+/−	−	+	+	+	13
Bicknell	2003	+	+	+	+	−	+	+	−	10
Shortell	2003	+	+	−	+/−	−	+	+	+	8
Komori	2004	−	+	+	+/−	−	+	+	−	6
Kudo	2004	+	−	+	+	−	+	+	+	8
Chiesa	2006	+	+	+	+	−	+	+	+	10
Pearce	2007	+	+	+	+/−	−	+	+	+	7
Wahlgren	2007	−	+	+	+/−	−	+	+	+/−	10
Knott	2008	+	+	+	+	−	+	+	+	11
Sharp	2008	−	+	+	+/−	−	+	+	−	8
Yeung	2008	−	+	+	+	−	+	+	+	11

+, Yes; −, no.
*Maximum score = 14.

Table II. Summary of data obtained from the included studies

First author	*Year*	*N*	*Age, mean y*	*Male %*	*JAA diameter, mean cm*	*Pre-op renal failure %*	*SVC %*	*Renal art procedures %*	*Cold renal perfusion*	*Renal ischemia time, mean min*	*Peri-op mortality %*	*New onset dialysis %*	*Postoperative renal dysfunction %*
Crawford	1986	94	68[a]	91[a]	NS	20[a]	92[a]	14[a]	—	19[a]	7.4	5.3	16[a]
Poulias	1992	38	66	100	NR	16	0	16	—	NR	5,3	13	NS
Allen	1993	31	NR	NR	NS	NR	39	23	selective	26	0	3.2	NR
Nypaver	1993	42	NS	NR	NR	NR	45	14	selective	NR	2.4	NR	NR
Taylor	1994	25	66[a]	96[a]	6.8[a]	16	81[a]	11[a]	—	21[a]	0	4.0	NS
Schneider	1997	23	72	NS	6.8	43	100	0	—	23	0	0	26
Jean-Claude	1999	122	71	80	NR	22	17	0	selective	28, 35[b]	NS	5.7	39
Guilini	2000	56	67	91	6	7	0	NS	—	20	3.6	1.8	14
Sasaki	2000	13	70	92	NS	0	8	31	—	44[c]	0	0	38
Ayari	2001	24	NR	NR	5.8	38	29	8	—	NS	4.2	0	NS
Sarac	2002	138	72	67	6.4	20	31	27	selective	32, 25[b]	5.1	5.8	28
Bicknell	2003	44	70	84	NS	NR	41	0	—	26	4.5	0	14
Shortell	2003	112	72	78	6.2	13	82	12	—	NS	6.3	3.6	13
Komori	2004	22	69	86	6	27	0	NS	—	38[c]	0	0	NS
Kudo	2004	18	66	56	NR	0	0	0	—	31	0	0	33
Chiesa	2006	81	69[a]	NS	NS	9	1[a]	0	selective	27	1.2	6.2	22
Pearce	2007	134	71	74	5.9	27	19	26	—	30	3	4.5	14
Wahlgren	2007	38	71	29	6	8	8	0	—	30	5.3	5.3	5
Knott	2008	126	74	78	6.3	17	21	12	selective	23	0.79	4.0	18
Sharp	2008	52	70	56	6	10	0	NS	—	27	0	0	NS
Yeung	2008	23	70	78	6.7	52	0	22	routine	37	0	0	0

JAA, Juxtarenal aortic aneurysm; *NR*, data is not retrievable specifically for non-ruptured JAA; *NS*, data is not stated in the article; *SVC*, supravisceral aortic cross-clamping.
[a]Mean data including minor proportion of ruptured JAA.
[b]Specified for suprarenal and supravisceral aortic cross-clamping, respectively.
[c]Calculated mean from subgroups.

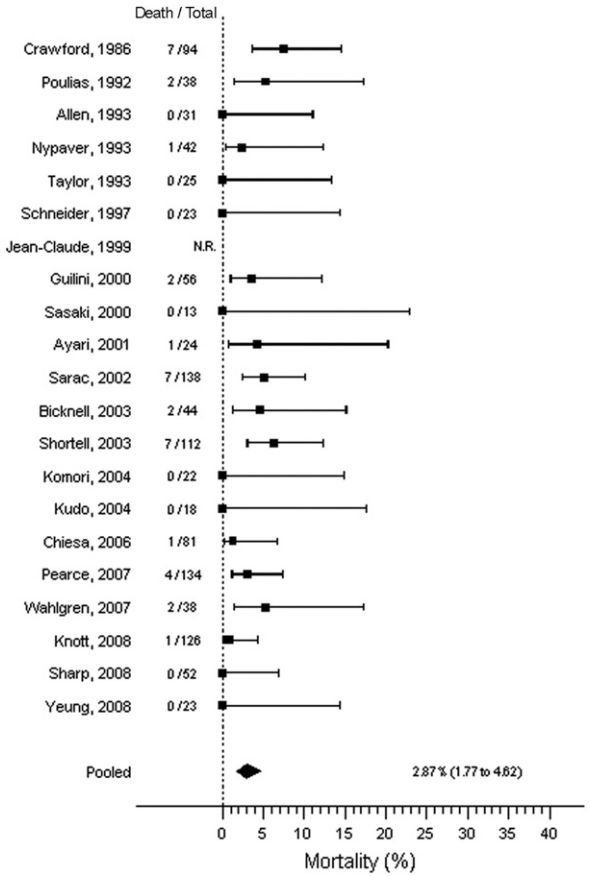

Fig 2. Forest plot showing postoperative mortality rate after open repair of non-ruptured juxtarenal aortic aneurysms. The *squares* and *horizontal lines* indicate point estimates and associated 95% confidence intervals (95% CI) for each study. The *diamond* at the bottom designates the random-effects pooled median mortality rate with 95% CI.

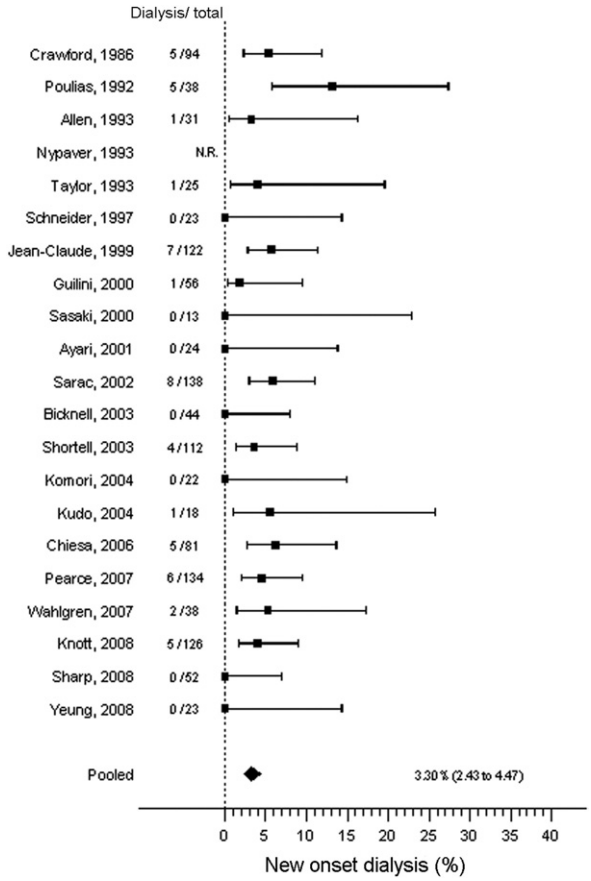

Fig 3. Forest plot showing postoperative incidence of new onset renal dialysis after open repair of non-ruptured juxtarenal aortic aneurysms. The *squares* and *horizontal lines* indicate point estimates and associated 95% confidence intervals (95% CI) for each study. The *diamond* at the bottom designates the random-effects pooled median incidence of new onset renal dialysis with 95% CI.

tion after non-ruptured JAA repair varied widely between the 13 studies and ranged from 0% to 39% (median, 18%). Postoperative morbidity was poorly documented and ill-defined. Therefore, valid morbidity rates could not be derived.

Preservation of renal function. Thirteen authors described the use of intravenous medication prior to suprarenal cross-clamping to protect renal function. This was performed routinely[1,4,6,7,51,52,54-56] or selectively.[3,57-59] Administration of mannitol was used most often,[7,52,55,56,59] sometimes in combination with furosemide[1,4] or dopamine.[3,6,51,54,58] Chiesa et al used fenoldopam mesylate and methylprednisolone instead of mannitol and dopamine in some cases.[51] Sasaki et al used continuous dopamine infusion during renal ischemia time.[57] In seven studies, the use of cold renal perfusion is reported.[1,4,6,10,51,52,55] Both cold crystalloids[1,10] and cold Ringer's solutions[4,51,55] were used. In some cases, mannitol or other additives were used.[4,51,55] In most studies, renal perfusion was performed only in selected patients with preoperative renal insufficiency or when prolonged renal ischemia was anticipated.[1,4,6,51,52,55] Only Allen et al reported the number of patients who received renal perfusion (n = 8).[1] Median incidence of new onset of dialysis for studies using selective renal perfusion was 5.7% (range, 3.2%-6.2%). In studies that did not report the use of selective renal perfusion, the median new onset of dialysis was 2.7% (range, 0%-13%). In one study, cold renal perfusion was performed routinely in all patients, with no postoperative renal dysfunction.[10] None of the studies compared the effects of renal protective measures with a control group.

Three authors examined the influence of preoperative renal insufficiency on the incidence of postoperative renal dysfunction. Both Sarac et al and Shortell et al reported that preoperative renal insufficiency was a significant risk factor for postoperative renal dysfunction.[6,8] In contrast, Knott et al found preoperative renal insufficiency not predictive of postoperative renal dysfunction.[4]

Operative technique. Open JAA repair can be performed using supravisceral (above the level of the superior mesenteric artery or celiac trunk; SVC) or suprarenal aortic

Table III. Postoperative renal dysfunction

Author	*Year*	*Criteria for postoperative acute renal dysfunction*	*Postoperative renal dysfunction %*
Bicknell	2003	Serum creatinine level >1.7 mg/dL or a rise of serum creatinine level >0.67 mg/dL above baseline.	14
Allen	1993	Serum creatinine level of >1.8 mg/dL or a rise of serum creatinine level >1.2x above baseline.	12[a]
Sarac	2002	Serum creatinine level >1.8 mg/dL or a rise of serum creatinine level >1.5x above baseline.	28
Crawford	1986	Serum creatinine level >2.0 mg/dL.	16[b]
Sasaki	2000	Serum creatinine level 2.0 mg/dL.	38
Wahlgren	2007	Serum creatinine level >2.0 mg/dL or a rise of serum creatinine level >1.5x above baseline.	5
Jean-Claude	1999	Rise of serum creatinine level >0.5 mg/dL above baseline.	39
Giulini	2000	Rise of serum creatinine level 0.5 mg/dL above baseline.	14
Knott	2008	Rise of serum creatinine level 0.5 mg/dL above baseline.	18
Yeung	2008	Rise of serum creatinine level 0.5 mg/dL above baseline.	0
Shortell	2003	Rise of serum creatinine level >1 mg/dL above baseline.	13
Chiesa	2006	Rise of serum creatinine level 1 mg/dL above baseline.	22
Schneider	1997	Rise of serum creatinine level >1.2x above baseline.	26
Pearce	2007	Rise of serum creatinine level >1.2x above baseline and a serum creatinine level >1.5 mg/dL in a male and 1.3 mg/dL in a female.	14
Nypaver	1993	Rise of serum creatinine level >1.5x above baseline.	17[a]
Kudo	2004	Rise of serum creatinine level 1.5x above baseline.	33
Poulias	1992	No individual data on serum creatinine levels and/or no criteria for renal dysfunction.	
Taylor	1993		
Ayari	2001		

[a]Combined data for juxtarenal and suprarenal aortic aneurysm repair.
[b]Combined data for non-ruptured and ruptured juxtarenal aortic aneurysm repair.

cross-clamping (above the renal arteries, but below the superior mesenteric artery; SRC). SVC was used in 15 out of 21 studies; in 4 studies, SVC was used primarily.[7-9,15] Three authors analyzed influence of clamp placement on mortality and morbidity after JAA repair. Sarac et al found that mortality after SVC was significantly higher compared with SRC (odds ratio [OR], 6.1; 95% CI, 1.1-32.9), and that SVC also was a risk factor for postoperative renal insufficiency (OR 3.3, 95% CI, 1.4-7.8), despite shorter clamping times.[6] Neither Shortell et al and Knott et al found SVC to be a statistically significant risk factor for mortality or postoperative renal dysfunction.[4,8] From 18 studies, a detailed description of the surgical approach could be derived. In all studies, a transperitoneal approach was used for at least some of the patients. The use of a retroperitoneal approach was described in 12 studies. Three authors predominantly used a retroperitoneal approach. Only Bicknell et al described the use of a thoracoabdominal approach in four patients.[4,50] In a retrospective study, Wahlgren et al compared the retroperitoneal approach (n = 20) with the transperitoneal approach (n = 18).[59] They reported that the transperitoneal approach was associated with significantly greater blood loss and longer suprarenal cross clamp times. Mortality and morbidity did not differ significantly, however.

DISCUSSION

Repair of juxtarenal aortic aneurysms, if compared with infrarenal aortic aneurysms, is characterized by more extensive mobilization of viscera to achieve adequate exposure of the abdominal aorta and by a period of renal ischemia, potentially increasing operative risk, especially the risk of postoperative renal dysfunction.

The results of our systematic review indicate that open repair of non-ruptured JAA can be performed with an acceptable operative mortality rate. Postoperative deterioration of renal function is a common complication; however, new onset hemodialysis was reported in a mere 3.3% of patients. Unfortunately, included studies used a wide variety of definitions for reporting incidence of postoperative acute renal dysfunction, hindering accurate comparison and interpretation of the reported data. Some authors defined renal dysfunction as a rise of postoperative serum creatinine level above a predetermined level, without reckoning with preoperative serum creatinine levels, leading to overestimation. In 2004, the Acute Dialysis Quality Initiative workgroup proposed a multilevel classification system for acute kidney injury, RIFLE.[16] It provides a uniform definition of acute kidney injury, with the ability to identify different stages of disease progression. We propose the use of this classification system for future studies in order to better compare and interpret renal function outcome.

Several authors reported the peroperative use of intravenous medication or renal perfusion to preserve renal function after JAA repair. Various techniques were used in performing renal perfusion. A comparative analysis of renal cooling was not performed because heterogeneity of the included studies was low for mortality and new onset dialysis, while reported data for acute renal dysfunction were not comparable. Therefore, the value of cold renal

perfusion in preserving renal function after JAA repair remains unclear. Importantly, the benefits of cold renal perfusion in thoracoabdominal aortic aneurysm repair have been well established.[60]

There is discussion in the literature regarding optimal placement of the proximal aortic clamp and optimal operative approach. Advocators of supravisceral cross-clamping state that it decreases the risk for distal embolization, because the supravisceral aorta is less likely to have significant atherosclerotic disease, while retraction and manipulation of large aneurysms is also avoided.[7,8,58] Adversaries point out that SVC does induce visceral ischemia, increases the risk for visceral embolization, and increases cardiac after load.[52,55,58] Data from the included studies suggest that both SVC and SRC can be executed safely, without major differences in outcome. Careful evaluation of the extent of atherosclerotic disease at the pararenal aorta is important before deciding on optimal aortic clamping site in a patient. Several authors suggest that SRC may be preferred in patients without significant atherosclerosis or thrombus at the suprarenal aorta, thereby avoiding visceral ischemia and minimizing cardiac stress.[4,6,55,58]

Considering a transperitoneal versus a retroperitoneal approach to the juxtarenal aorta, the former has the advantage of giving better exposure of the right renal artery and intra-abdominal cavity.[1,55] A retroperitoneal approach to the aorta avoids abdominal adhesions and interference with the left renal vein and may be preferred in obese patients.[55,58,59] This technique may furthermore offer better exposure of the suprarenal and visceral aorta. Based upon the studies included in this systematic review, no definite conclusions can be drawn towards superiority of either technique in open JAA repair in general. Optimal surgical approach should be determined for patients individually, considering aneurysm extent, anticipated clamp location, and body habitus.

Median renal ischemia time was 27 minutes; unfortunately, reported data was insufficient to draw any conclusion regarding its effect on postoperative renal dysfunction.

This systematic review is limited by the relative small number of studies included, and the long time interval represented. During this long period, improvements in operative and perioperative care have been made, which are likely to have improved patient outcomes, although heterogeneity beyond what could be expected by chance alone was small. No randomized trials were found, and most studies were retrospective in design. A large number of studies reported combined results of SAA and JAA repair, and only from a minority of these studies specific results for JAA repair could be derived. Concluding from this review, open repair of JAA can be performed with an acceptable postoperative mortality rate; however, postoperative deterioration of renal function is a common complication. Further studies are required to elucidate optimal operative techniques and the value of specific protective measures such as renal cold perfusion.

AUTHOR CONTRIBUTIONS

Conception and design: VJ, KY, GT, WW
Analysis and interpretation: VJ, KY, GA, JR, GT
Data collection: VJ, DH
Writing the article: VJ, KY, DH
Critical revision of the article: GA, JR, GT, WW
Final approval of the article: VJ, KY, GA, DH, JR, GT, WW
Statistical analysis: VJ, JR
Obtained funding: N/A
Overall responsibility: VJ

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